HLW-SDT-99-0354
Revision: 3

SAVANNAH RIVER SITE

HIGH LEVEL WASTE SALT DISPOSITION
SYSTEMS ENGINEERING TEAM

APPLIED TECHNOLOGY INTEGRATION SCOPE OF WORK MATRIX FOR CST NON-ELUTABLE ION EXCHANGE (Demonstration Phase)

APPROVED:__________________________ **DATE:**________________
DOE HLW Assistant Manager

APPROVED:__________________________ **DATE:**________________
WSRC Program Manager

Change Control Record

Document Name	*Unique Identifier*
Science & Technology Work Scope Matrix for CST Non-Elutable Ion Exchange (Demonstration Phase)	HLW-SDT-99-0354

Summary of Changes

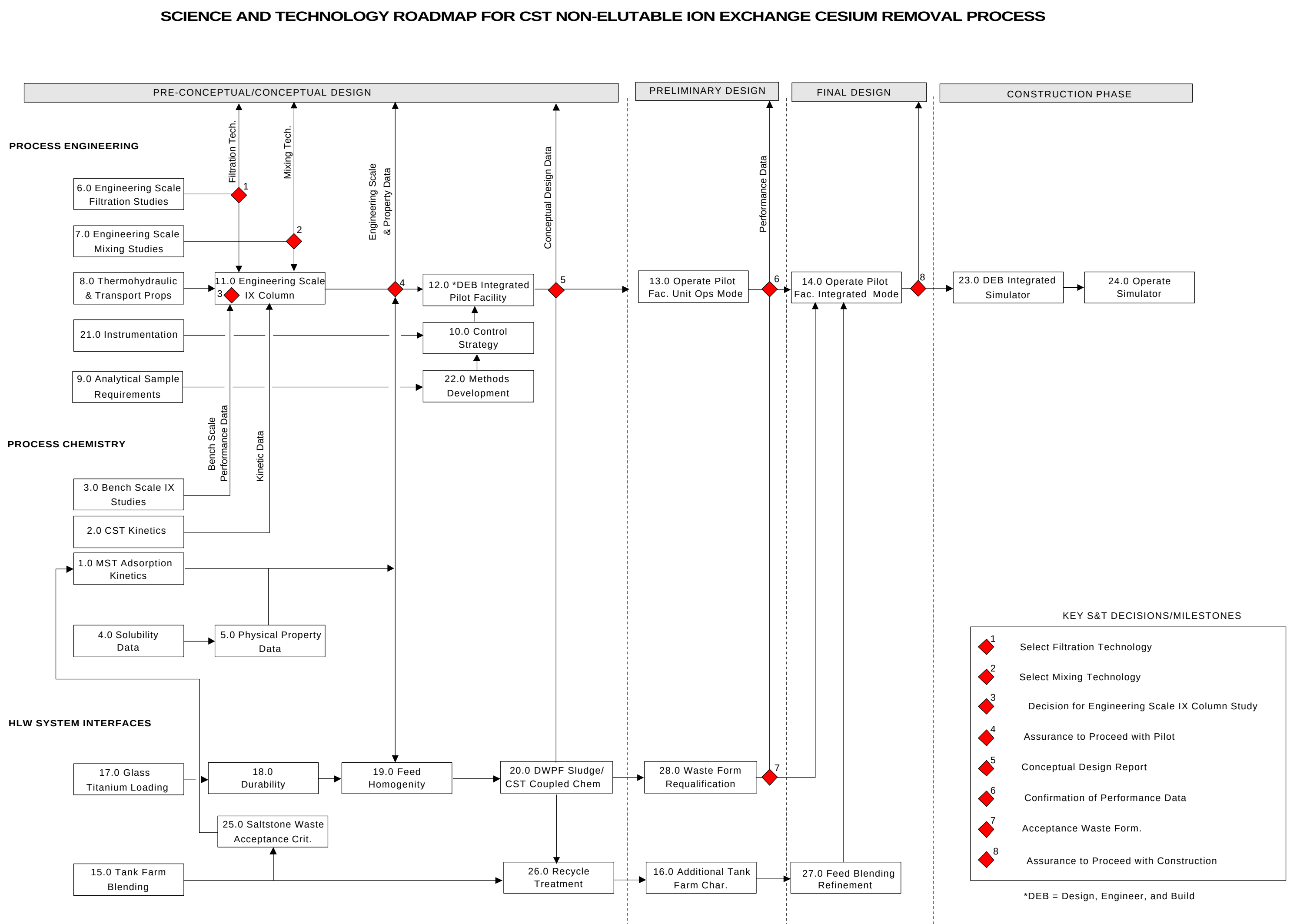
Revision Date	*Matrix Revision*	*BCF Number(s)*	*Reasons for change*	*Items Affected by the change*
December 2, 1999	0	NA	Initial Issue	NA
December 27, 1999	1	NA	Incorporates ECF # HLW-SDT-99-0387 which added TTR/TTP/TR references, ties to uncertainty IDs, updates to reflect feedback from TTR/TTP development and incorporated minor editorial comments	All changes identified with revision bars
January 10, 2000	2	NA	Incorporates ECF# HLW-SDT-2000-00010 which aligned workscope matrix with finalized FY00 approved workscope and incorporated DOE review comments by removing holds and identifying work to be initiated in FY01 and incorporated minor editorial comments.	All changes identified with revision bars
February 15, 2000	3	NA	Incorporates ECF# HLW-SDT-2000-00050 which removed information from items common to all three technologies that are now being controlled through Alpha Removal workscope matrix HLW-SDT-2000-00047 and changed Section 9.0 to show WSRC overview of UOP R&D.	All changes identified with revision bars

Use of Workscope Matrix

This Workscope Matrix has been developed to define the Science and Technology (S&T) development activities to be performed during the Demonstration Phase. The guiding document for this Workscope Matrix is the HLW Salt Disposition SE Team Science and Technology Roadmap (Attachment 1). The S&T Roadmap provides the technology development path forward towards successful deployment of the CST Non-Elutable Ion Exchange option. This matrix (Attachment 2) expands on the roadmap by providing the high level details of each segment of research and development, assigning responsibility for the execution of each segment and documenting the path through each segment of R&D in the form of a logic diagram(s) (Attachment 3). The logic diagrams tie to the S&T Roadmap using numbered key S&T decisions/milestones.

In this Demonstration phase, Scale-up will be performed wherever practical and advantageous to the confirmation of technology and application of technology to the full-size facility. The Workscope Matrix provides an additional definition of at which scale the S&T development is to be conducted.

ATTACHMENT 1 – Science and Technology Roadmap



ATTACHMENT 2 - CST Non-Elutable Ion Exchange Work Scope Matrix

Item No.	Item	Considerations	Scale	Lead Org.	Path Forward Doc.	Reference Doc.	Uncertainty
Process Chemistry							
1.0	MST Adsorption Kinetics	*The addition of Monosodium Titanate (MST) has been proposed to adsorb the soluble U, Pu, and Sr contained in the waste stream. The rate and equilibrium loading of these components as a function of temperature, ionic strength and mixing is required to support the batch reactor design. Initial data from batch reactor data indicates the MST kinetics require more than the 24 hrs assumed in pre-conceptual design resulting in larger reactor batch volumes. Studies will be conducted to determine if the MST strike could be completed in the existing SRS waste tanks. Alternatives to MST will be investigated.* MST adsorption kinetics experiments have been performed at 7.5 M and 4.5 M Na+. As currently flowsheeted, the Alpha Sorption step for CST would be performed at 5.6 M Na+. Also, questions have been raised regarding the oxidation states of Pu (initial, as a function of ionic strength, and equilibrium as Pu is adsorbed onto MST) and the effect of oxidation states on MST adsorption rates. Since Pu is the primary source of alpha, it is important to assure that experimental results obtained with simulants are representative of performance with real wastes. Activities to resolve these issues are common to CST, TPB and CSEX, Refer to Alpha Removal Workscope Matrix (HLW-SDT-2000-00047) for further details.					
2.0	CST Kinetics	*The ability of CST to remove Cs from aqueous waste solutions needs to be investigated as a function of temperature and waste composition. Potassium, strontium, nitrate, and hydroxide are known to impact the equilibrium loading of Cs on the CST. Mass transfer coefficients as a function of column geometry and velocity vs. diffucivity must also be determined to ensure proper ion exchange column sizing. The ability of CST to sorb Sr, Pu and U must be determined to avoid potential criticality issues. De-sorption of the Cs due to normal and abnormal operations such as temperature swings must be determined. Thermal stability of CST must be determined.* During Phase IV experiments, observations led to questions regarding the presence and fate of excess materials, "dry back" fines, lot-to-lot variability, chemical and thermal stability, and predictability of resin performance in SRS waste. Significant additional effort is required to understand the implications and to assure applicability to SRS processing requirements. In fact, the resin may have to be "reengineered" to meet SRS needs. 2.1 Work with UOP to: 2.1.1 Eliminate or remove excess materials 2.1.2 Eliminate or reduce chloride or change to nitrate form 2.1.3 Eliminate or reduce attrition 2.1.4 Reduce lot-to-lot variability (Develop rapid, reliable tests(s) to detect lot-to-lot variability - short term kinetics/pore diffusion test) 2.1.5 Pretreatment of reengineered resin	Lab	UOP	HLW-SDT-TTR-99-34.0[1] WSRC-RP-99-01079[2] HLW-SDT-TTR-99-36.1[1] TBD-Later (UOP) HLW-SDT-TTR-99-36.2[1] TBD-Later (UOP) WSRC-RP-99-01079[2] HLW-SDT-TTR-99-38.1[1] WSRC-RP-99-01079[2] HLW-SDT-TTR-99-38.2[1] ORNL/CF-99/67[2]	HLW-SDT-99-0238[3] WSRC-TR-99-00313[3] HLW-SDT-99-0273[3] WSRC-TR-99-00312[3] WSRC-TR-99-00374[3]	11, 13, 15, 29, 31

Note: See Matrix Legend for definition of column content

Item No.	Item	Considerations	Scale	Lead Org.	Path Forward Doc.	Reference Doc.	Uncertainty
		2.1.6 Improve the particle size distribution of IE-9xx as it is produced					
		2.1.7 Finalize re-engineered form					
		2.2 Resolve/understand CST chemical stability issues					
		2.2.1 Long term exposure					
		2.2.1.1 Expose CST to waste at normal operating temperatures for 8 – 9 months and then perform standard column run	Lab	ORNL			
		2.2.1.2 Stability/precipitation during NaOH pretreatment and exposure to 5.6 M waste – proprietary constituents • Static and dynamic exposure with frequent solution replenishment • Varying salt composition and temperature • Solid characterization • Effect on pore size (macro and micro) • K_d measurement and column run at end of exposure	Lab	SRTC			
		2.3 Resolve/understand CST thermal stability issues					
		2.3.1 Thermal/equilibrium desorption/leaching • Understand mechanism by which Cs was leached in ORNL tests • Leaching? CST phase change? shift in equilibrium?	Lab	SRTC			
		2.3.2 Determine why Cs did not reload after temperature dropped					
		2.3.2.1 Using simplified salt solution (e.g., 2 M NaOH) determine the rate of Cs-137 desorption from loaded CST (IE-910, IE-911, and binder if available) as a function of temperature – tests would include cycling temperature from 25 to 50-80 °C	Lab	UOP			
		2.3.2.2 Contract with Sandia National Laboratory to provide consulting services	NA	SNL			
		2.4 Expand the understanding of cesium removal kinetics and CST capacity for other actual tank wastes by examining Cs, Sr, and actinide removal efficiency for various radioactive waste matrices in inventory at SRS	Lab	SRTC			
		2.4.1 Obtain small dip samples (approx. 100 mL) from the different SRS waste tank supernates and perform Kd measurements and waste characterization for elemental composition					
		2.5 Second generation CST - Determine if CST can be re-engineered to adsorb alpha (i.e., Pu) ? : e.g., add a Pu adsorbant with the IE-911 to form a combined, engineered resin that would remove Cs, Sr, and Pu?	Lab	UOP			
3.0	Bench Scale IX Studies	*Radioactive bench scale column tests must be conducted to determine the radiolytic generation rate of hydrogen and other gases. These gases represent potential safety and column operational issues.*			HLW-SDT-TTR-99-31.1[1] WSRC-RP-99-01079[2] HLW-SDT-TTR-99-31.2[1]	WSRC-TR-99-00308[3] WSRC-TR-99-00285[3] HLW-SDT-99-0248[3]	11, 33

Note: See Matrix Legend for definition of column content

Item No.	Item	Considerations	Scale	Lead Org.	Path Forward Doc.	Reference Doc.	Uncertainty
		Due to various constraints, we were unable to run the small column flowing test in a radiation field during Phase IV. These tests would investigate the impact of gas formation (both radiolytic and non-radiolytic) on the CST performance of a flowing column.			ORNL/CF-99/66[2]	HLW-SDT-99-0257[3]	
		3.1 Provide better understanding of large column behavior to guide design interpretation of small column tests 3.1.1 Improve calculations of gas generation in large columns 3.1.2 Define rate and location of bubble formation as Cs loading progresses 3.1.3 Estimate diffusion rates of gases out of CST particles, compare to generation rate and confirm with experiments	NA	SRTC			
		3.2 Demonstrate and measure the effect of internal and external bubbles on Cs sorption 3.2.1 Determine method for generating gas bubbles in macro channels (including method to verify pressure and volume) 3.2.2 Measure rate of sorption of Cs in CST w/ and w/o bubbles (use Kd or flowing column tests at 1 Mrad/hr	Lab	SRTC/ ORNL			
4.0	Solubility Data	*Solubility of various salts must be determined to define the lower bounds of operating temperature and minimum tank farm dilution requirements.*			HLW-SDT-TTR-99-31.1[1] WSRC-RP-99-01079[2]		Design Input
		4.1 Determine H_2 and O_2 solubility as a function of temperature, Na+ concentration, and salt composition.	Lab	SRTC			
5.0	Physical Property Data	*General physical property data such as density, viscosity, yield stress and consistency of slurries, as a function of state variables such as temperature is required to support the design effort. Settling velocity and re-suspension requirements must be determined.* At least one case of column plugging was observed and attributed to post-precipitation of aluminates from simulant. Also, others (UOP and ORNL) have stated that dilution of real wastes must be performed with NaOH to avoid gibbsite and alumino-silicate precipitation. It is necessary to develop an understanding of simulant preparation and waste dilution that prevents post-precipitation that could cause column plugging. Using a combination of bench-top experiments and high-ionic strength solution modeling to:			HLW-SDT-TTR-99-37.1[1] WSRC-RP-99-01079[2] HLW-SDT-TTR-99-37.2[1] ORNL/CF-99/65[2] HLW-SDT-TTR-99-38.2[1] WSRC-RP-99-01079[2]	WSRC-RP-99-00597[3] WSRC-TR-99-00219[3] WSRC-RP-99-00836[3]	11, 35
		5.1 Develop an understanding of and prevention of post-precipitation in waste simulants and modify simulants if required 5.1.1 Determine how to dilute waste solutions to prevent precipitation and post-precipitation of aluminates, alumino-silicates, and any other insoluble salts that may form due to dilution 5.1.2 Perform scoping tests to examine the chemistry of leached Si and Nb, silica contained in the salt solution and the associated soluble Al. 5.1.3 Measure the effects of the chemistries on the K_d for CST (IE-911) desorption/resorption at two temperatures 5.1.4 Examine CST surfaces with solid characterization techniques	Lab	SRTC			

Note: See Matrix Legend for definition of column content

Item No.	Item	Considerations	Scale	Lead Org.	Path Forward Doc.	Reference Doc.	Uncertainty
		(XRD, BET, SEM, IR, and Raman)					
		5.2 Determine the effect of carbonate, oxalate and peroxide on the capacity and Cs removal kinetics 5.2.1 Measure adsorption isotherms for a range of cesium starting concentrations 5.2.2 Develop new coefficients for ZAM model 5.2.3 Perform K_d measurements with different anion concentrations to determine magnitude of fouling of CST – utilize WPT γ-counter, SEM, IR, Raman	Lab	SRTC/ Texas A&M			
		5.3 CST Capacity 5.3.1 Extend data on IE-911 (includes binder) capacity as function of temperature in various salt solutions 5.3.2 Include comparisons of nitrate form and IE-910	Lab	SRTC			
Process Engineering							
6.0	Engineering Scale Filtration Studies	*Filtration of MST and sludge is required to prevent plugging of the ion exchange column. Initial data indicates low flux rates for the filtration of these solutions requiring large filter areas and high axial velocity for cross flow filtration techniques. Alternative filtration techniques and filter aides will be studied, and a selection made. Filtration cleaning studies including the impact of spent cleaning solution will be studied.* Tests for MST/sludge filtration (Alpha Sorption step) performed during Phase IV (FY99) indicate low crossflow filter fluxes leading to very large filters. Improvement in filter size and operation is desired. Activities to resolve these issues are common to CST, TPB and CSEX, Refer to Alpha Removal Workscope Matrix (HLW-SDT-2000-00047) for further details.					
7.0	Engineering Scale Mixing Studies	*As noted in the kinetic section above good reactor mixing is essential to proper alpha decontamination batch reactor sizing. Simple mixing by agitation or recirculation may not be adequate. Alternate mixing technologies will be studied. Resuspension criteria must be developed.* No scope for FY00	NA	NA	NA		34
8.0	Thermo-hydraulic and Transport Properties	*Thermal and hydraulic properties must be determined to allow for determination of heat removal loads and technologies (jacketed vessels, cooling coils, heat exchanger, etc.). The crush strength of the CST is especially important. Determination of the CST minimum transportation and fluidization velocity is required.* Many questions/concerns about the CST process are related to equipment design and operation. These have not been previously addressed and have been carried as uncertainties and risks. A number of these questions/concerns will be addressed.			HLW-SDT-TTR-99-32.1[1] WSRC-RP-99-01117[2] ORNL/CF-99/68[2] HLW-SDT-TTR-99-32.2[1] ORNL/CF-99/68[2]	HLW-SDT-99-0133[3] HLW-SDT-99-0141[3] WSRC-TR-99-00116[3] WSRC-TR-99-00313[3] WSRC-TR-99-00285[3] WSRC-SDT-99-0257[3] WSRC-TR-99-00374[3]	2, 3, 4, 6, 7
		8.1 Investigate pre-conceptual designs for moving packed beds and fluidized	NA	NA			

Note: See Matrix Legend for definition of column content

Item No.	Item	Considerations	Scale	Lead Org.	Path Forward Doc.	Reference Doc.	Uncertainty
		beds (Work to be initiated in FY01) 8.1.1 Hire a consultant for preliminary evaluation of alternative configurations and other fixed bed configurations 8.1.2 Develop a pre-conceptual design for each technology recommended by the consultant					
		8.2 Investigate improvements in current fixed packed bed design (Work to be initiated in FY01) 8.2.1 Simplify valving 8.2.2 Reduce complexity of column changeout activities	NA	NA			
		8.3 Investigate pre-conceptual designs' gas disengagement equipment 8.3.1 Test selected designs	Large Column	ORNL			
		8.4 Measure heat transfer characteristics of CST column with gas bubbles (Work to be initiated in FY01)	Lab	ORNL			
9.0	Analytical Sample Requirements	*The analytical sample requirements including on-line analysis must be developed to support control strategy development.* Develop an at line analyzer for Cs, Sr, and total alpha. Activities to resolve these issues are common to CST, TPB and CSEX, Refer to Alpha Removal Workscope Matrix (HLW-SDT-2000-00047) for further details					
10.0	Control Strategy	*Control Strategy must be developed to support the designing, engineering, and building of the pilot facility.* No scope for FY00	NA	NA	NA		4
11.0 11.0	Engineering Scale IX Column	*The bench scale kinetic data, and remoteability requirements may indicate the need for intermediate scale ion exchange column testing prior to designing, engineering, and building of the pilot facility. Demonstration of the ability to remotely load and unload the columns is essential. Impact of column operation due to size reduction of the CST during operation is required.* No scope for FY00	NA	NA	NA		Design Input
12.0	Design, Engineer, and Build (DEB) Integrated Pilot Facility	*A pilot scale (to be determined) facility will be built to support the confirmation of design data and development of operator training.* No scope for FY00 Pilot plant planning began in FY99 but has been discontinued until a final technology selection is made.	NA	NA	NA		Design Input
13.0	Operation of the Pilot Facility in a Unit	*The pilot facility testing will include a phase of single unit operations to confirm bench scale property data, operational parameters and proof of concept component testing.* No scope for FY00	NA	NA	NA		Design Input

Note: See Matrix Legend for definition of column content

Item No.	Item	Considerations	Scale	Lead Org.	Path Forward Doc.	Reference Doc.	Uncertainty
	Operations Mode						
14.0	Operation of the Pilot Facility in an Integrated Operations Mode	*The pilot facility testing will include a phase of integrated operations to ensure the design will operate under upset conditions, determine the limits of operation to dictate recovery, the limits of feed composition variability, and confirm design assumptions. Investigation of the operating characteristics while varying the velocity, temperature and waste composition will be conducted. This testing will aid in operator training and simulator development, which in accordance with the overall project roadmap is completed during the construction phase of the project.* No scope for FY00	NA	NA	NA		Design Input
21.0	Instrument-ation	No scope for FY00	NA	NA	NA		Design Input
22.0	Methods Development	No scope for FY00	NA	NA	NA		Design Input
23.0	Design, Engineer and Build (DEB) Integrated Simulator	No scope for FY00	NA	NA	NA		Design Input
24.0	Operate Simulator	No scope for FY00	NA	NA	NA		Design Input
High Level Waste System Interface							
15.0 15.0	Tank Farm Blending	*The production sequences of emptying the tank farm has been studied in the past and have indicated potential tank blending issues regarding Np, U, Pu, and Sr. The current blend strategy must be reviewed to determine if alternate blending strategies can reduce the 5 to 8x concentration spikes in these components or if the alpha removal requirements must be modified to meet the Saltstone waste acceptance limits.* No scope for FY00	NA	NA	NA		Design Input
16.0	Additional Tank Farm Character-ization	*While the tank farm waste has been characterized, additional characterization may be required to define the range of expected compositions during facility operation.* No scope for FY00	NA	NA	NA		Design Input
17.0	Glass Titanium Loading	*The current waste qualification envelope is limited to 1 wt % TiO_2. The use of MST and CST increases the Ti loading to as much as 5 wt %. Re-qualification is therefore required.* No scope for FY00	NA	NA	NA	WSRC-TR-99-00245[3] WSRC-TR-99-00289[3] WSRC-TR-99-00291[3] WSRC-TR-99-00293[3] WSRC-TR-99-00384[3] WSRC-TR-99-00323[3]	12
18.0	Durability	*Initial data regarding the glass composition vs. durability correlation indicated that*	NA	NA	NA		Design Input

Note: See Matrix Legend for definition of column content

Item No.	Item	Considerations	Scale	Lead Org.	Path Forward Doc.	Reference Doc.	Uncertainty
		modification of this essential correlation is required. The initial parametric study indicated that all the CST containing glasses produced resulted in leach rates exceeding the 95% upper confidence interval of the existing correlation. Liquids and viscosity correlations may required updating. No scope for FY00					
19.0	Feed Homogeneity	*The DWPF waste qualification envelope is based on maintaining the proper ratio of solids to water throughout the process. Testing must be conducted to ensure the current agitation and sampling equipment in the DWPF is adequate.* Phase IV tests showed (1) as-received CST could be easily resuspended but did not form a uniform slurry in a DWPF-scaled tank, (2) as-received CST with sludge and frit plugged the Hydragard sampler, (3) size-reduced CST settled and compacted so that it was extremely difficult to break up and resuspend, and (4) size-reduced CST with sludge and frit was not representatively sampled (~12 % low in frit) by the Hydragard.			HLW-SDT-TTR-99-35.0[1] WSRC-RP-99-01115[2]	WSRC-TR-99-00244[3] WSRC-TR-99-00309[3]	28
		19.1 Develop representative SRAT/SME sampling of CST/sludge/frit slurry	Bench	SRTC			
		19.1.1 Determine cause for non-representative Hydragard sample of CST/sludge/frit slurry					
		19.1.2 Determine if uniformly size-reduced CST can be representatively sampled by the Hydragard					
		19.1.3 If necessary, modify the Hydragard to provide a representative sample					
		19.2 Develop and test size reduction method	NA	SRTC/ Vendor			
		19.2.1 Consult with West Valley, Hanford K-Basin, UOP					
		19.2.2 Identify acceptable equipment and characteristics					
		19.2.3 Obtain equipment and perform testing					
		19.2.4 Determine if CST needs to be pretreated and loaded					
		19.3 Evaluate on-line CST particle size analyzer	Bench	SRTC			
		19.4 Determine how to suspend CST in the DWPF	Bench	SRTC			
		19.4.1 Determine CST loading of discarded IX slurry					
		19.4.2 Develop relationship between wt% CST in slurry and SG of slurry (bench-scale experiment)					
		19.4.3 Mockup CST storage tank using TFL 1/240th scale SME					
		19.4.4 Suspend/resuspend size-reduced CST so as to assure uniform transfers					
		19.4.5 Resuspend and homogenize size-reduced and as-received CST; considerations include: • Glass-compatible additive to prevent compaction or aid dispersion • Agitator speed • Fluidic mixer • Sonics					

Note: See Matrix Legend for definition of column content

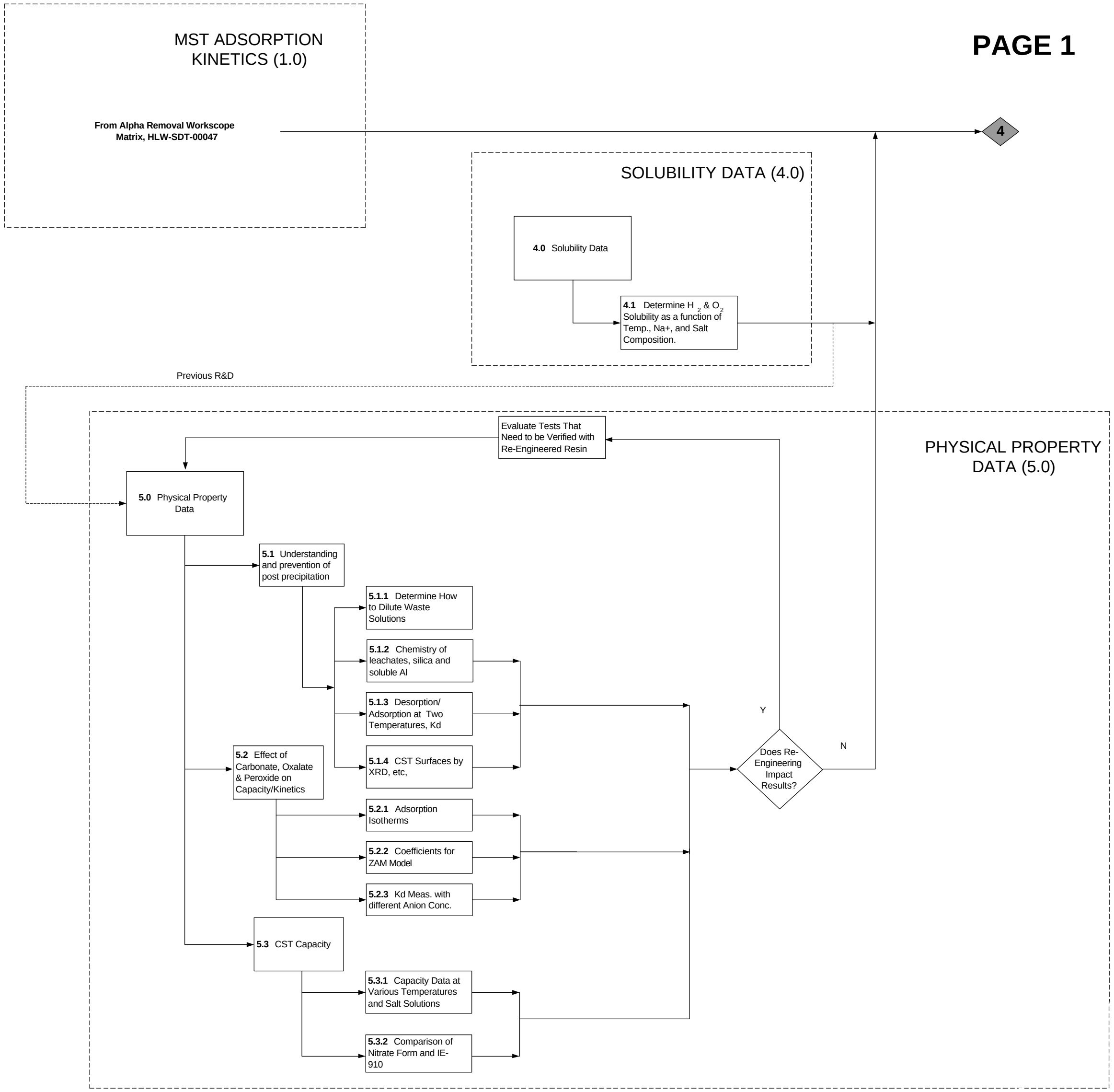
Item No.	Item	Considerations	Scale	Lead Org.	Path Forward Doc.	Reference Doc.	Uncertainty
		19.5 Demonstrate ability to feed CST/sludge/frit slurry to melter 19.5.1 Reconstruct the melter feed loop at the Thermal Fluids lab 19.5.2 Run tests sampling output of feed loop to demonstrate melter feed is representative of feed tank contents	Bench	SRTC			
20.0	DWPF Sludge/CST Coupled Chemistry	*Initial data indicated some foam formation during the DWPF feed preparation processes. Investigation into alternative antifoams is required. The impact on DWPF and tank farm operations must be assessed.* No scope for FY00	NA	NA	NA	WSRC-TR-99-00277[3] WSRC-TR-99-00302[3]	32, 28
25.0	Saltstone Waste Acceptance Criteria	No scope for FY00	NA	NA	NA		Design Input
26.0	Recycle Treatment	No scope for FY00	NA	NA	NA		Design Input
27.0	Feed Blending Refinement	No scope for FY00	NA	NA	NA		Design Input
28.0	Waste Form Requalification	No scope for FY00	NA	NA	NA		Design Input

Note: See Matrix Legend for definition of column content

Matrix Legend

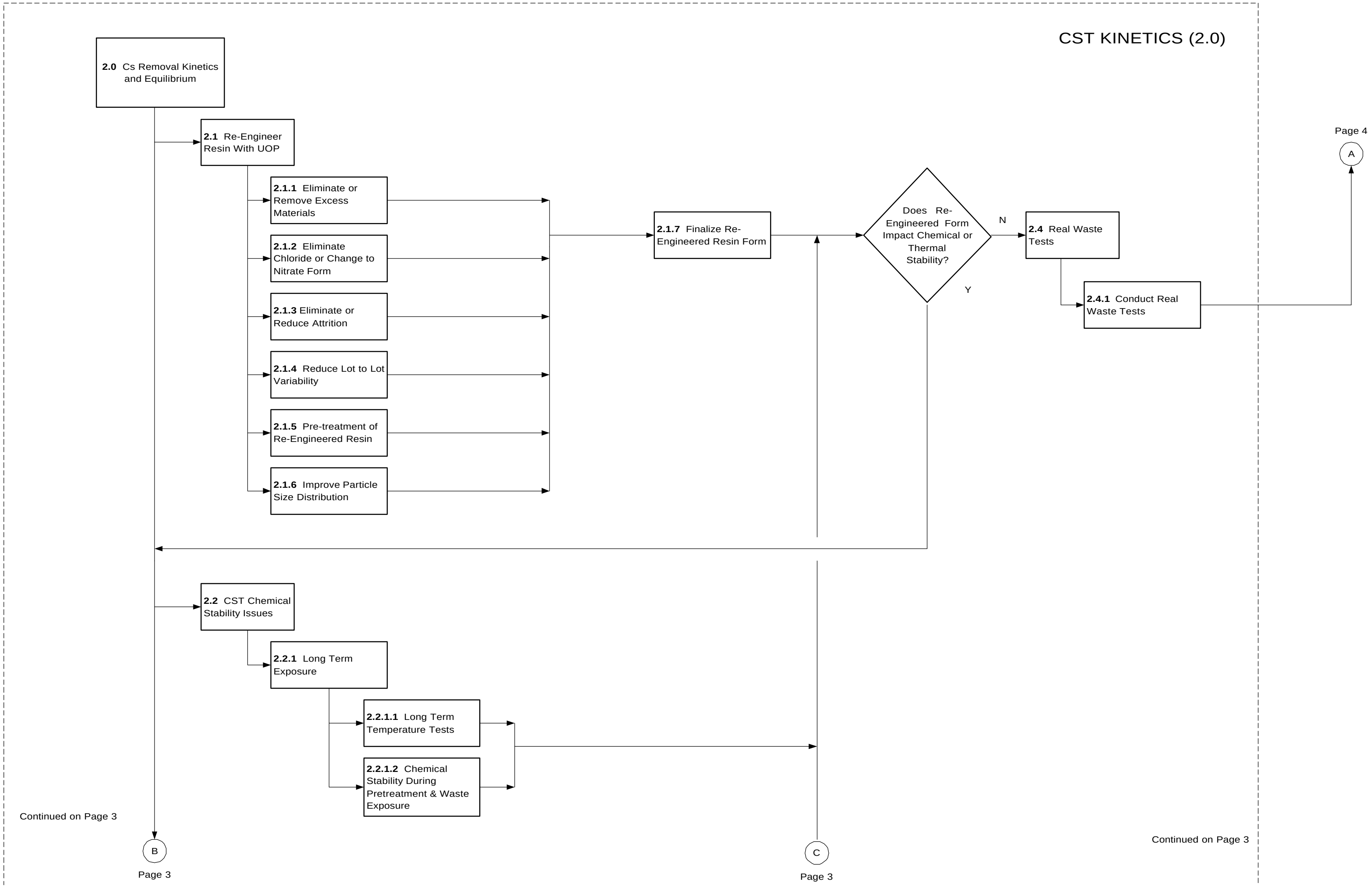
Item No.	Corresponds to the block number on the Science and Technology Roadmap and Logic Diagrams; provides a tie between documents.
Item	General title of the S&T block; corresponds to block title on the Science and Technology Roadmap and Logic Diagrams.
Considerations	Discusses the considerations pertinent to the completion and resolution of each item; provides details and numbered R&D activities to be performed to resolve the item (numbered R&D activities correspond to numbered activities on logic diagrams). Italicized text is extracted from previous CST roadmap HLW-SDT-980165 and reflects activities previously completed or no longer required.
Scale	Defines the scale at which R&D test will be performed (Lab scale, bench scale, engineering scale or pilot scale).
Lead Org.	Identifies the organization responsible for conducting the R&D activity and hence location where activity will be performed.
Path Forward Doc.	Lists the applicable Technical Task Requests (TTRs) denoted xxxx[1]; Task Technical and Quality Assurance Plans (TTPs) denoted xxxx[2] and Test Reports (TRs) denoted xxxx[3] which respectively initiate, plan and document the results of R&D activities.
Reference Doc.	Lists reference documents such as previous test results, reviews etc., which relate to the current R&D activity.
Uncertainty	Provides a cross-tie to the cost validation matrix uncertainty statement Ids within the Decision Phase Final Report, WSRC-RP-99-00007.
NA	Not Applicable

ATTACHMENT 3 - CST Non-Elutable Ion Exchange S&T Logic Diagrams (1 of 5)

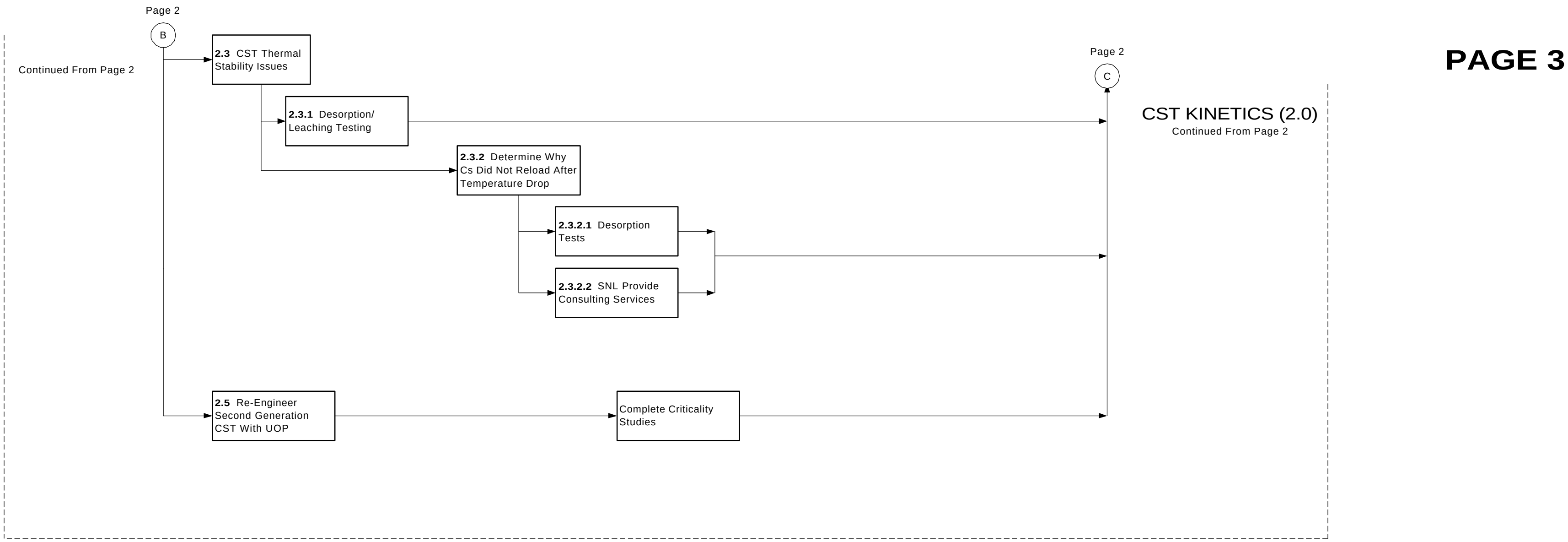


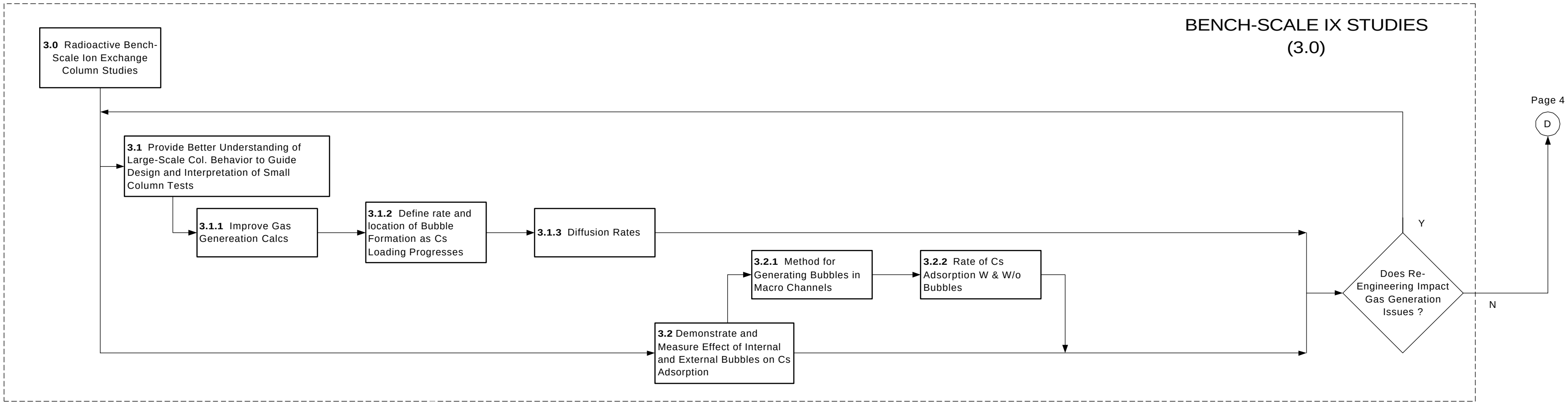
ATTACHMENT 3 - CST Non-Elutable Ion Exchange S&T Logic Diagrams (2 of 3)

PAGE 2

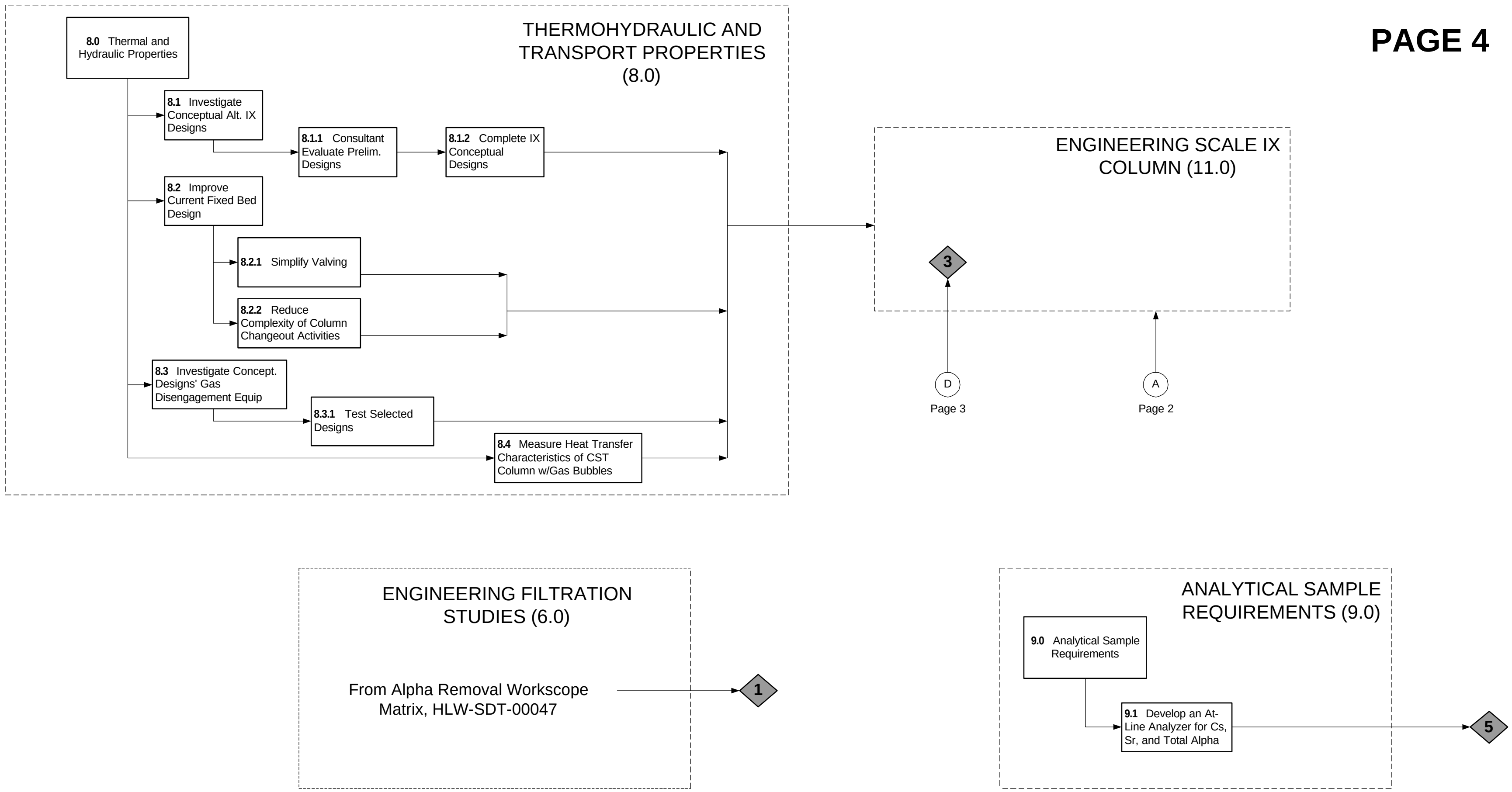


ATTACHMENT 3 - CST Non-Elutable Ion Exchange S&T Logic Diagrams (3 of 5)





ATTACHMENT 3 - CST Non-Elutable Ion Exchange S&T Logic Diagrams (4 of 5)



ATTACHMENT 3 - CST Non-Elutable Ion Exchange S&T Logic Diagrams (5 of 5)

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